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INVESTIGATION OF THE RELATIONSHIP BETWEEN THE UPPER IONOSPHERE DRIFTS AND THE CURRENTS SYSTEMS OF THE DYNAMO-REGION AT MIDDLE AND HIGH LATITUDES

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SUMMARY

The behavior of the drift of ionosphere's F_2-region is considered from the standpoint of the motor theory. The observed drift is compared with the computed one and with the daily course of the horizontal component of the Earth's magnetic field. The relationship between the current system of the dynamo-region and the drift in the F_2-region of the ionosphere at middle and high latitudes is confirmed.

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According to the "motor" theory [1], the drift occurs in the F_2-region of the ionosphere as a result of action of the dynamo-region's electric field on the ionospheric plasma situated in the Earth's magnetic field. With some simplifying assumptions, one may demonstrate how the drift in the upper ionosphere is linked with the geomagnetic variations, which are the consequence of current in the dynamo-region, that is, in the lower ionosphere. For known values of the magnitude of dynamo-region's electric field and of the Earth's magnetic field, the drift velocity in the F_2-region may be computed by the formula [2]:

$$V = c\frac{[\bar{E}x\bar{H}_T]}{H_T^2},\qquad (1)$$

where $\bar{E}$ and $\bar{H}_T$ are the vectors of the electric and geomagnetic field strength.

(*) ISSLEDOVANIYE SVYAZI DREYFOV VERKHNEY IONOSFERY S TOKOVYMI SISTEMAMI DINAMO-OBLASTI V UMERENNYKH I VYSOKIKH SHIROTAKH

The magnitude of the field E is determined from the known variations of the Earth's magnetic field

$$\operatorname{rot} \delta H_T = \frac{4\pi}{c} j. \qquad (2)$$

Here H_T is the variation of the geomagnetic field, i [ ]E, a[ ] is the tensor of ionosphere conductivity. Because of slow H_T variations, we may neglect to displacement cureent. According to Baker and Martyn [3], for a thin spherical layer the conductivity current components are expressed in the following manner:

$$j_y = \sigma_{xy} E_x + \sigma_{yy} E_y, \quad j_x = \sigma_{xx} E_x + \sigma_{xy} E_y, \qquad (3)$$

where σ_{xx}, σ_{xy} and σ_{yy} are the components of ionosphere conductivity tensor.

Since in the formation of dynamo-currents electrons and ions of the whole lower ionosphere participate, there arises the necessity of computing the integral conductivities:

$$k_{xx} = \int_{z_0}^{z} \sigma_{xx}\, dz, \quad k_{xy} = \int_{z_0}^{z} \sigma_{xy}\, dz, \quad k_{yy} = \int_{z_0}^{z} \sigma_{yy}\, dz, \qquad (4)$$

where z_0 is the lower, and z is the upper boundary of the dynamo-region, basically contributing to the integral conductivity. When the latter are known and the data on the variations of the Earth's magnetic field are available, the drift velocity components in the F_2-layer may be determined by the formulas:

$$V_{\text{с-ю}} = \frac{2}{3} \frac{c^2}{4\pi \sin I \cdot H_T} \frac{k_{yy}\delta H_x - k_{xy}\delta H_y}{k_{xy}^2 + k_{xx}k_{yy}}, \qquad (5)$$

$$V_{\text{в-з}} = -\frac{2}{3} \frac{c^2}{4\pi \sin I \cdot H_T} \frac{k_{yy}\delta H_y + k_{xy}\delta H_x}{k_{xy}^2 + k_{xx}k_{yy}}. \qquad (6)$$

Here I is the magnetic inclination, and δH_x and δH_y are the variations of the Earth's magnetic field in the horizontal plane, expressed in γ ($\gamma = 10^{-5}$oe).

In order to establish the relationship of the drifts of ionosphere's small-scale inhomogeneities with the current systems of the dynamo-region, we examined the material obtained during the observation of drift by a method of closely-spaced reception at time of the 8-th and 9-th Antarctic expeditions to "Mirnyy" Observatory and during combined expeditions of IZMIRAN USSR and IGY in 1966-1967 in Tbilisi. The variations of the Earth's magnetic field in the days when drift observations were made, were borrowed in magnetic observatories situated no farther than 100 km from the place of observation.

Observations of drift of small-scale inhomogeneities were begun at Mirnyy Observatory in 1963.[4]. The expedition provided the possibility of observing a drift in the polar cap region, where the bulk of geophysical events has a quite peculiar course and differ notably from the low and middle-latitude ones. Figure 1 illustrates the link of the east-west drift velocity component in the F_2-layer (dots) with the behavior of variation of geomagnetic field's horizontal component in the region of the Mirnyy Observatory (δH - crosses). The results represent the mean value of the drift and of variations δH for 2 days, namely, 10 October and 20 November 1963, when the behavior of the field was almost identical. Plotted in the same figure is the course of the computed east-west component of drift velocity (dashes)

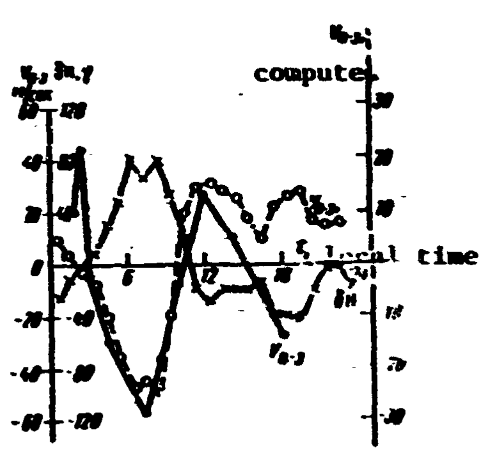

Fig.1

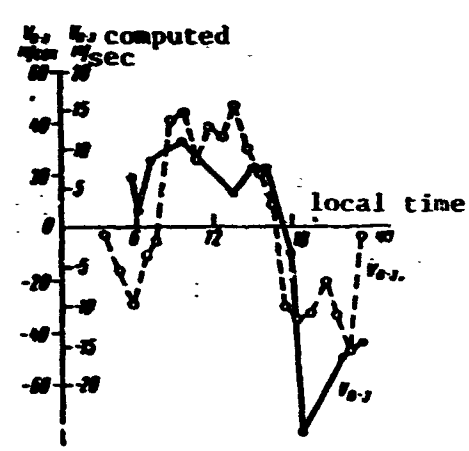

Fig.2

The calculation was performed according to (6), where the integral conductivities were computed by the initial data of [4] in the 100 - 130 km altitude range and constituted: $k_{xx} = 1.5\cdot10^{12}$, $k_{yy} = 1.08\cdot10^{12}$ and $k_{xy} = 10.5\cdot10^{12}$ $cm\cdot sec^{-1}$.

Taking the obtained integral conductivities into account, we shall finally obtain

$$V_{N-S} = -(0.11\delta H_x + 0.78\delta H_y), \quad V_{W-E} = -0.76\delta H_x + 0.11\delta H_y,$$

where V_{N-S} and V_{W-E} are expressed in m sec^{-1}, and δH_x and δH_y in gammas (γ). The analogy in the behavior of the computed and observed east-west component of the drift velocity is satisfactory. In particular, the correlation factor between them is $\rho = 0.72$

A large experimental material on drift of small-scale inhomogeneities was obtained during the expedition to Tbilisi, which is located in the region of the center of the current system, responsible for the S_g-variations of the Earth's magnetic field. Analysis of the experimental material has shown a satisfactory resemblance in the behavior of the east-west component of the drift velocity with the variations of the horizontal component of the Earth's magnetic field [5, 6]. Let us compare, for example, the results of harmonic analysis of the observed and computed east west component of drift velocity for the date of 4 December 1966. Data on drift were obtained during processing of fading readings by the correlation analysis method:

$$V_{observ.} = 0{,}67 + 70\sin(t + 12{,}4) + 22\sin 2(t - 3{,}1) + 17\sin 3(t - 1{,}7) + \\ + 25\sin 4(t + 1{,}7),$$

$$V_{computed} = 0{,}9 + 39\sin(t + 11{,}8) + 19.4\sin 2(t - 3{,}1) + 5{,}3\sin 3(t - 0{,}9) + \\ + 23\sin 4(t - 0{,}8),$$

where t is expressed in hours and the harmonic components of drift velocity in m·sec^{-1}.

As may be seen, the phases of the first two harmonics of the computed and observed drift velocity components differ little from one another. The constant velocity components are quite small, while the higher order harmonics are significant, which is characteristic for points situated in the band of current system's center passage. The first harmonic prevails over the second, which is correct for the F_2-layer of the ionosphere.

Finally, the existence of link between the drift in the F_2-layer and the dynamo-currents of the lower ionosphere is still further corroborated by the experiments conducted near Moscow during the IGY and IYQS. As an example for the IYQS we plotted in Fig.2 the course of the observed and computed east-west component of drift velocity of F_2-layer's small-scale inhomogeneities for 29 July 1965. Fig.3 illustrates an analogous pattern for the IGY (average for 15 April and 26 May 1959 . Both examples demonstrate the good coincidence in the behavior of the computed and observed east-west component of drift velocity. The correlation factor for the curves of Fig.2 is $\rho = 0.78$, and for the curves of Fig.3 $\rho = 0.92$.

It should be noted, however, that, as in the earlier described experiments, the magnotude of the velocity of the observed drift is greater by a factor of (1.5 – 4) than that computed. The calculation of drift velocity components for the Moscow conditions was performed by the formulas

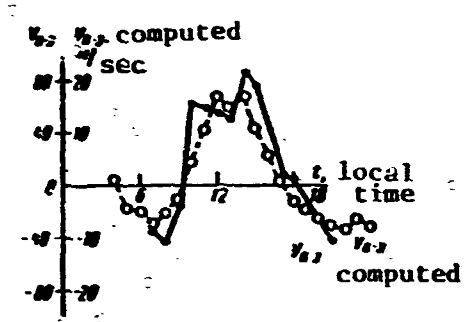

Fig.3

$$V_{N-S} = 0.35\delta H_x - 0.48\delta H_y; \quad V_{W-E} = -(0.48\delta H_x + 0.31\delta H_y).$$

Analysis of hhe variations of the Earth's magnetic field component has shown that the amplitude of these variations is greater during the IGY than during the IYQS, which is apparently explained by the increase in the conductivity of the ionosphere in the period of high solar activity. The drift velocity in the F_2-layer is inversely proportional of integral conductivity, which explains to some measure the observed increase of drift velocity during the IYQS as compared with the IGY [7]. The conductivity of the ionosphere changes notably in the course of a day [8]. It is substantially greater in daytime than during the night, which must lead to an increase of drift velocity in nighttime. The numerous observations of drift in the F_2-layer corroborate this conclusion.

Comparison of the north-south drift velocity components obtained from the experiment and computed by formula (5), indicates in most of the cases a satisfactory resemblance in the behavior of the observed and computed drift velocity components for the same rate of velocities as for the east-west component. An exception is shown at Mirnyy, where the computed and observed north-south components are close to one another.

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REFERENCES

1. S. CHAPMAN, J. BARTELS. J. Geomagnetism, 2, 750 - 794, 1940.
2. H. MAEDA. Inst. Physics and Phys. Soc., 187, 190, 1963.
3. W. G. BAKER, D. MARTYN. Philos. Trans. Roy. Soc., 246A, 281, 1953.
4. A. A. KASHIN, F. P. KLIMANOV, V. V. KUSHNEREVSKIY ET AL. Geom. i Aeronomiya, 6. 1, 1120, 1966.
5. G. M. AROSHIDZE, V. A. ZAGULYAYEVA, A. A. KASHIN ET AL, Ib. 6, 3, 548, 1967.
6. V. A. ZAGULYAYEVA, A. A. KASHIN. "Trudy Vsesoyuznoy Konf.po nauchnym itogam MGSS (Proc. of All-Union Conf on Scientific Results of the IYQS) in print, 1968.
7. A. A. KASHIN, YU. V. KUSHNEREVSKIY, L. K. NEROVNYA ET AL. Sb'Ionosfernyye Issledovaniya" 15, 48, 1968.
8. M. N. FATKULLIN. Geomagnetizm i Aeronomiya, 6, No.3, 586, 1964.

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